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MINIMUM QUANTITY LUBRICATION WITH TIMER BASED CONTROL IN MACHINING OF EN9 MATERIAL

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Abstract - *This paper presents a experimental study on machining operation on components from EN9 (C-45 Plain carbon steel) . My project sponsored company* ***M/s Paramount Industries, Chinchwad*** *, produce blanks for gear cutting from the EN9 materials. The conventional inserts are used in the turning operations of the components. For these component turning using conventional inserts has shown moderate to low production rates , lower surface finish and dimensional inaccuracies at time of machining components.*

The conventional method of lubrication in which the coolant pump is used to circulate cooling fluid, this method is more costly and also the machine, environment conditions were affected, hence it was decided to implement the minimum quantity lubrication system along with timer on the machine. Minimum quantity lubrication (MQL) has recently found its way into the area of metal cutting machining and, in future many areas has as an alternative to conventional wet processing method. In contrast to traditional lubrication, minimum quantity lubrication system takes only a few drops of lubrication (approx. 5 ml to 50 ml per hour) in machining. Due to MQL we improved in surface finish &quality of product. Also reduced manufacturing time as well cost.

Key Words: *MQL ,Surface roughness, EN9 material ,Timer based machining.*

1. RELEVANCE:

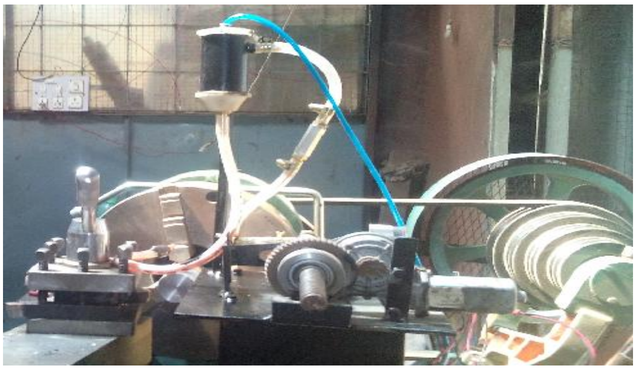
Minimum quantity lubrication (MQL) has recently found its way into the area of metal cutting machining and, in future many areas has as an alternative to conventional wet processing method. In contrast to traditional lubrication, minimum quantity lubrication system takes only a few drops of lubrication (approx. 5 ml to 50 ml per hour) in machining. Today, the enormous cost-saving potential resulting from doing almost today we are able to produce cylinder heads, crankcases, camshafts and numerous other components made of common materials such as steel, cast iron and aluminums using MQL in the framework of highly automated large volume production. The advantages of MQL is clear. With respect to occupational safety, MQL offers more effective than water-mixed metalworking fluids. A major advantage is the substantially better compatibility related to skin care. MQL lubricants are fatty-alcohol or ester based. Additives against pollution, e.g. biocides and fungicides, are not necessary at all, since microbial growth is more possible in an aqueous phase. The extreme reduction of lubrication quantities 5 ml to 50 ml per hour results in nearly dry work pieces and chips. This lubricants reduces health hazards caused by emissions of metalworking fluids in breathed-in air and on skin of employees at their workplaces. These lubricants do not spread throughout the area around the machine, thus making for a cleaner workplace. Costs generated by conventional lubrication are no higher an issue with minimum quantity lubrication.

1.1 INTRODUCTION

MQL consists of a mixture of pressurized air and oil micro-droplets applied directly into the interface between the tool and chips. However, the question of how the lubricants can decrease the friction under very high temperature and loads is still not answered especially for long engagements times. MQL decreased the contact length compared to dry cutting for both short and long engagement time. Minimum quantity lubrication (MQL) has increasingly found its way into the area of metal cutting machining and, in many areas, has already been established as an alternative to conventional wet processing. In contrast to flood lubrication, minimum quantity lubrication uses only a few drops of lubrication (approx. 5 ml to 50 ml per hour) in machining. Today, the enormous cost-saving potential resulting from doing almost entirely without metalworking fluids in machining production is recognized and implemented by many companies, primarily in the automotive industry. While in the early 1990s small applications (sawing, drilling) were done “dry”, today we are able to produce cylinder heads, crankcases, camshafts and numerous other components made of common materials such as steel, cast iron and aluminum using MQL in the framework of highly automated large volume production.

The advantages of this new technology are clear. With respect to occupational safety, MQL offers numerous advantages over water-mixed metalworking fluids. A major advantage is the substantially better compatibility concerning skin care. Minimum quantity lubrication is a total-loss lubrication method rather than the circulated lubrication method used with emulsions. This means using new, clean lubricants that are fatty-alcohol or ester based. Additives against pollution, e.g. biocides and fungicides, are not necessary at all, since microbial growth is possible only in an aqueous phase. The extreme reduction of lubrication quantities results in nearly dry work pieces and chips. This greatly reduces health hazards caused by emissions of metalworking fluids in breathed-in air and on the skin of employees at their workplaces. Metalworking fluids do not spread throughout the area around the machine, thus making for a cleaner workplace. The present work experimentally investigates the role of MQL on surface roughness of EN9 material with help of timer based controlling in machining process.

EXPERIMENTAL TEST SETUP



SCHEMATIC OF MQL SYSTEM

The MQL system comprises of following parts

a) **Lubricant tank & frame** : These are fabricated structural components of the MQL with primary functions of tank to hold the MQL lubricant and the frame to support the entire assembly of the MQL system

b)**Dispenser actuator** : The dispenser actuator is a double acting hydraulic cylinder with 32mm bore and 100 mm stroke , thus the dispenser volume is 80 cc , ie in one stroke of the dispenser it is possible to dispense 80 ml of MQL lubricant. The rate of displacement of the dispenser piston is thus important to determine the minimum quantity of oil dispensed per min.

c)**Dispenser Actuator driving mechanism** : The forward stroke of the displacer piston is used for the dispensing activity where as the return stoke charges the dispenser. The reciprocating motion of the piston is achieved using a power screw and nut arrangement. The power screw is greeped in a nut supported in ball bearing in a bearing housing. The nut carries an spur gear driven by an spur pinion mounted on the geared motor. The geared motor under consideration is specified below

Motor is an 12 volt DC motor , with following specification:
Voltage : 12 Volt DC
Power = 20 watt
Mounting : Face mounted

Motor rotates in clockwise and counter clockwise directions to effect the forward and reverse motion of the screw and thereby the piston. Motor speed is regulated by speed regulator where as the direction control is done using a direction control 2 pole -2 way switch.

d) **Inlet circuit to dispenser :** The inlet circuit to the dispenser is used a non-return valve opening into the cylinder side and closing on the tank side. This allows lubricant flow from the lubricant tank to the cylinder during suction stroke where as prevents reverse flow from the cylinder to tank during dispensing stroke.

e) **Dispensing Circuit :** Dispensing circuit connects the outlet of cylinder to the mixing chamber. The circuit comprises the an non return valve opening into the mixing chamber side and closing on the cylinder side. This allows lubricant flow from the cylinder to mixing chamber during dispensing stroke where as prevents reverse air flow from the mixing chamber to cylinder during suction stroke. Circuit also has flow control valve for fine adjustments of flow rate of lubricant to mixing chamber, and pressure gage indicates the pressure in the delivery line.

f) Mixing chamber : Mixing chamber is the device that mixes the MQL lubricant and the compressed air to create lubricant mist to be directed onto the cutting action area to serve a three fold purpose ;

i) Lubricate the tool tip and job contact area during cutting to minimize the friction between them, thereby reducing the heat produce. Misty nature of the lubricant ensures effective application of lubricant and better heat extraction.

ii) The second advantage of using compressed air mist that, it helps chip evacuation from the cutting area which is one of the major reasons of development of 'built-up-edges ' on tool tip leading to reduced tool life and improper surface finish on job.

iii) The compressed air offer other advantage that , fumes that are likely to be developed due to burning of the lubricant are not developed due to the high velocity of the lubricant particles (they do not reach flash point).

g)**Flex hose with interchangeable nozzle :** The flex hose connects the mixing chamber and the nozzle , two set of spray nozzle with tip diameters1.5 and 2.0 mm are provided for spraying.

WORKING :

A) DISPENSER CHARGING CYCLE :

Motor is rotated in clockwise direction that rotates the nut in counter clockwise direction due to spur gearing , nut rotate and screw is constrained to translate hence it moves back thereby moving the piston in backward direction thereby effecting the suction stroke. The inlet circuit to the dispenser is used a non-return valve opening into the cylinder side and closing on the tank side. This allows lubricant flow from the lubricant tank to the cylinder during suction stroke where as prevents reverse flow from the cylinder to tank during dispensing stroke.

B) DISPENSER DELIVERY CYCLE :

Motor is rotated in counter-clockwise direction that rotates the nut in clockwise direction due to spur gearing , nut rotates and screw is constrained to translate hence it moves forward thereby moving the piston in forward direction thereby effecting the delivery stroke. Dispensing circuit connects the outlet of cylinder to the mixing chamber. The circuit comprises the an non return valve opening into the mixing chamber side and closing on the cylinder side. This allows lubricant flow from the cylinder to mixing chamber during dispensing stroke where as prevents reverse air flow from the mixing chamber to cylinder during suction stroke. Circuit also has flow control valve for fine adjustments of flow rate of lubricant to mixing chamber, and pressure gage indicates the pressure in the delivery line.

MOTOR

The drive motor is 12 VDC motor coupled to an planetary gear box.
Specifications of motor are as follows:
A) Power 15 watt
B) Speed = 30 rpm
C) Gear box : Planetary /epicyclic type (reduction ratio : 1:5)
d) Mounting dimensions (Face mounted M12 x 1.5) pitch
–OUTPUT SPEED – 30RPM

DESIGN OF PARTS

DESIGN OF SPUR PINION & GEAR

Stage 1: Drive as GEAR and pinion arrangement

Maximum load =Maximum torque / Radius of gear

Maximum torque = 4.7 N-m

No of teeth on gear = 60

Module = 1.5 mm

Radius of gear by geometry = (60 x 1.5) /2=45mm

Maximum load = T/r = 4.7 x 10^3 /45 =104 N

b = 10 m

Material of spur gear and pinion = Nylon 66

Sult pinion = Sult gear = 300 N/mm^2

Service factor (Cs) = 1.5

The gear and pinion arrangement where as pinion has 10teeth and gear has 60 teeth share the entire tooth load…

⇒Pt =(W x Cs) 156 N.

Peff = 156 N (as Cv =1 due to low speed of operation)

Peff = 156 N --------(A)

Lewis Strength equation

WT = Sbym

Where ;

Y= 0.484 – 2.86 Z⇒ yp = 0.484 - 2..86 = 0.198

yg = 0.484 – 2.86 = 0.436

⇒ Syp = 59.4

Syg = 130.8

As Syp < Sys ⇒ pinion is weaker

W_T = (Syp) x b x m

=59.4 x 10m x m

W_T= 594m^2----------(B)

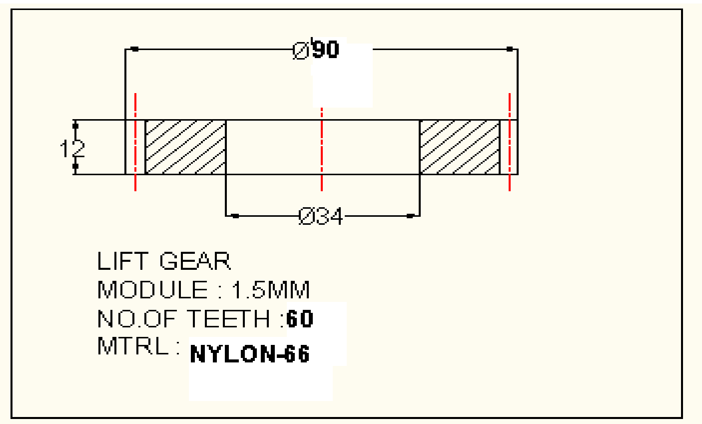
Equation (A) & (B)

594 m^2 = 156

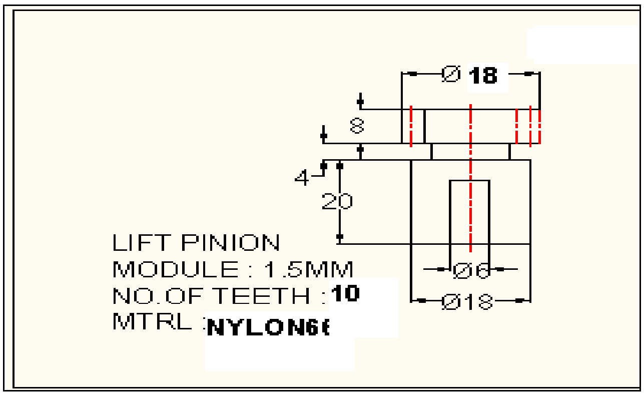
⇒m=51 mm

selecting standard module = 1.5 mm for ease of construction as we go for single stage gear box making the size compact achieving maximum strength and proper mesh.

Hence gear pair dimensions are as follows,



Material	Allowable tensile stress N/mm²	Allowable shear stress N/mm²
Phosphor bronze	**400**	**210**



POWER SCREW

A power screw is a mechanical device meant for converting rotary motion into translation motion and for transmitting power. The main application of power screws are as follows.,

1. To raise load, eg. Screw jack
2. To obtain accurate motion in machining operations , eg lead screw of lathe.
3. To clamp work piece eg. Vice
4. To load specimen, eg universal testing machine.

The main advantage of power screws is their large load carrying capacity with small overall dimensions. Power screws are simple to design, easy to manufacture and give an smooth and noiseless service. Power screw provides large mechanical advantage and highly accurate motion.

Screw jacks are primarily used to raise loads, and are often operated manually. But in some peculiar applications as in changing the angular positions of heavy TV antennas, or parabolic solar panels it becomes difficult to operate these mechanisms manually, as the changes are frequent.

In such cases it is required to have an lifting device that can be power operated (electrically operated), as well as that can give accurate motion.

Electrical jack is an solution to the above problem where in an mechanical screw is driven by an electrical motor coupled to an worm gear box and is operated by power effectively for raising as well as lowering the load

DESIGN OF NUT

In design of nut the major dimension is the height or length of the nut. It is decided by the considering the bearing. Nut is also required to be safe under shearing load condition. The shear failure of nut is takes place at its core diameter and the area of core diameter of screw resisting shear is less than the area at the core diameter of nut. Secondly the materials for nut & screw are choose different to avoid higher friction at contacts.

Design the nut

$$f_{bearing} = \frac{W}{\pi/4\,(d^2 - dc^2) \times n}$$

$$= \frac{5826}{\pi/4\,(24^2 - 18^2) \times 11}$$

n = 5

AS ; n = no of the threads in contact.

ln = length of nut.

P = Pitch.

$$n = \frac{Ln}{p}$$

$\Rightarrow$ Ln = n x p

= 5 x 6

ln = 30

Normally it is recommended that ratio of length or height of nut (n) **to core** diameter (dc) should be between 1.2 to 2.5 for solid nuts.

ln = 1.2x 30

=36 mm

Considering length of nut = 36 mm

DESIGN CHECK FOR PISTON ROD

INPUT DATA

1. Theoretical force at 6 bar when advancing of piston = 754 N

2.Piston rod threading end = M10 x 1.25 pitch

Design of piston rod

Material selection:

Ref :- (PSG – 1.12)

Designation	Tensile Strength N/mm^2	Yield StrengthN/mm^2
EN24	800	680

Direct Tensile or Compressive stress due to an axial load :-

$$fc_{act} = \frac{W}{A}$$

$$fc_{act} = \frac{754}{4 \times 8.75^2}$$

As $fc_{act} < fc_{all}$; Piston rod is safe in compression.

3. Shear stress in threaded end due to axial load

$$fs_{act} = \frac{W}{\pi\, n\, dc\, t}$$

t = width thread at r

t= 0.625 mm

n = No of threads in contact = AM/ pitch = 30/1.25 = 24

$$fs_{act} = \frac{754}{\pi x24x8.75x0.625}$$

= 1.82 N/mı

As ; $fs_{act} < fs_{all}$, the screw threads are safe in shear.

STANDARD INSERT

INPUT DATA:

MACHINE : CENTRE LATHE

MATERIAL : EN9 (C45)

BRINELL HARDNESS : 95-145

CUTTING TOOL : STANDARD INSERT

CONDITION : WITHOUT APPLICATION OF MQL

RECOMMENDED SPEED & FEED :

ROUGHING ---SPEED ---450 ----Maximum depth of cut 2.00 mm

FEED ---0.3 MM/rev---- ----Maximum depth of cut 2.00 mm

FINISHING ---SPEED ------1050 -----Maximum depth of cut 0.60 mm

FEED ---0.05 ---- ----Maximum depth of cut 0.6 mm

FIT : CLEARANCE

TOLERANCE : USL (50.3)

LSL (50.00)

Stresses due to buckling of piston rod :-

According to Rankine formula,

Where

$$Wcr = \frac{fc \ A}{1 + a\,(le/k)^2}$$

Where ; Wcr = Crippling load on screw (N)

A = Area of c/s at root (mm^2)

A= constant

Le= Equivalent unsupported length of screw (mm)

decided by end conditions.

K= Radius of gyration = dc/4 (mm)

Fc= Yield stress in compression (N/mm^2)

le = 0.707L;as one end of screw are considered to be fixed and other free(Ref . PSG Design Data Pg. No. 6.8)

Here transverse of the piston is 40 mm, total length of piston rod =(Zj + AM)

=80 +30 =110

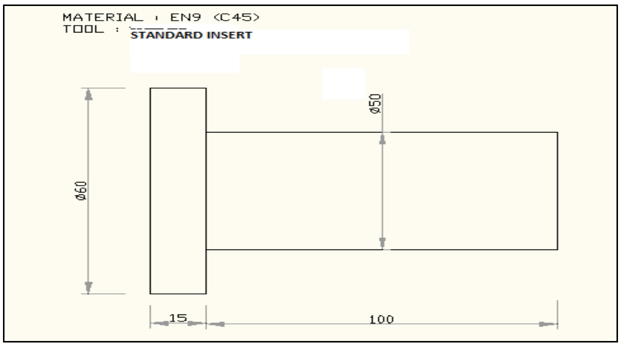
$\Rightarrow$ le = 0.707 x 110 = 77mm

$$Wcr = \frac{400 \times (\pi/4 \times 8.75^2)}{1+(1/7500)(77/(8.75/4))^2}$$

Wcr =66.03 X 10^3 N = 66.03 kN

As, The critical load causing buckling (**66.03 kN)** is high as compared to actual compressive load of 3.016 kN the piston rod is safe in buckling **.**

WORK PIECE GEOMETRY



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RESULT AND DISCUSSION

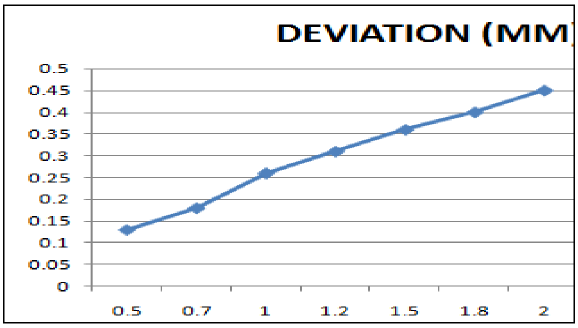
OBSERVATIONS TABLE ---A (ROUGHING)

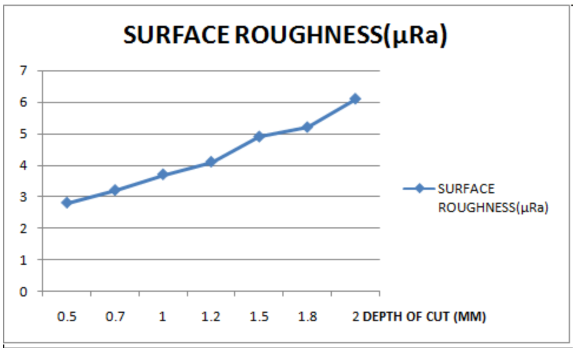
SPEED = 450 RPM

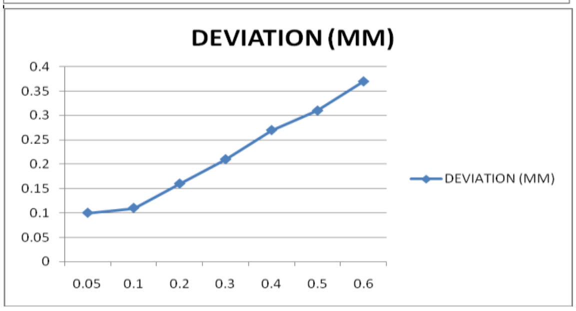
FEED = 0.3

SR. NO	SPEED (RPM)	FEED (MM/REV)	DEPTH OF CUT (MM)	DIMENSION	DEVIATION	Surface Roughness µRa
1.	450	0.3	0.5	50.13	0.13	2.8
2.	450	0.3	0.7	50.18	0.18	3.2
3.	450	0.3	1.0	50.26	0.26	3.7
4.	450	0.3	1.2	50.31	0.31	4.1
5.	450	0.3	1.5	50.36	0.36	4.9
6.	450	0.3	1.8	50.40	0.40	5.2
7.	450	0.3	2.0	50.45	0.45	6.1

Graph of Deviation Vs Depth of cut at 450 rpm , 0.3 mm feed (mm/rev) , For machining EN9 using STD insert without use of MQL







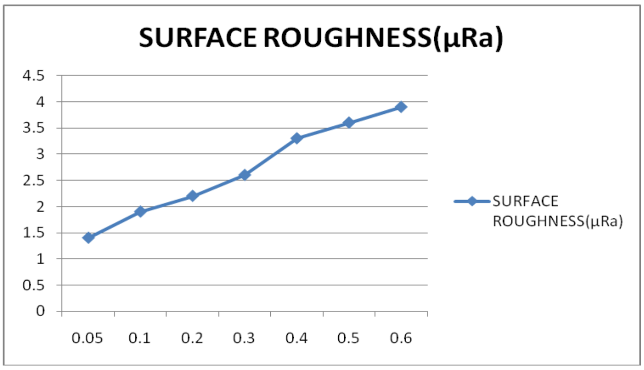
OBSERVATIONS TABLE --b (Finishing)

SPEED = 1050 RPM

FEED = 0.05

SR. NO	SPEED (RPM)	FEED (MM/REV)	DEPTH OF CUT (MM)	DIMENSION	DEVIATION	Surface Roughness µRa
1.	750	0.05	0.05	50.10	0.10	1.4
2.	750	0.05	0.1	50.11	0.11	1.9
3.	750	0.05	0.2	50.16	0.16	2.2
4.	750	0.05	0.3	50.21	0.21	2.6
5.	750	0.05	0.4	50.27	0.27	3.3
6.	750	0.05	0.5	50.31	0.31	3.6
7.	750	0.05	0.6	50.37	0.37	3.9

Graph of Deviation Vs Depth of cut at 1050 rpm , 0.05 mm feed (mm/rev) , For machining EN9 using standard insert without MQL

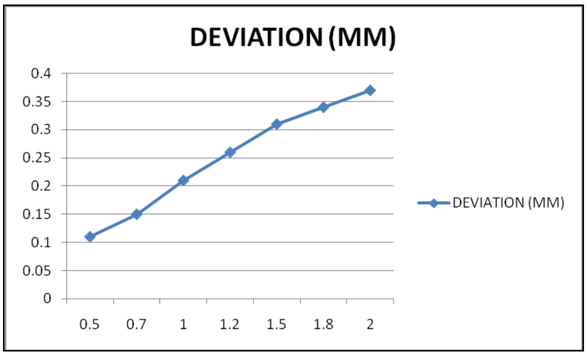


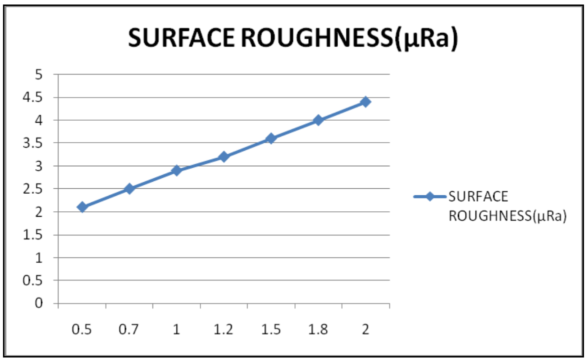
OBSERVATIONS TABLE ---A (ROUGHING)

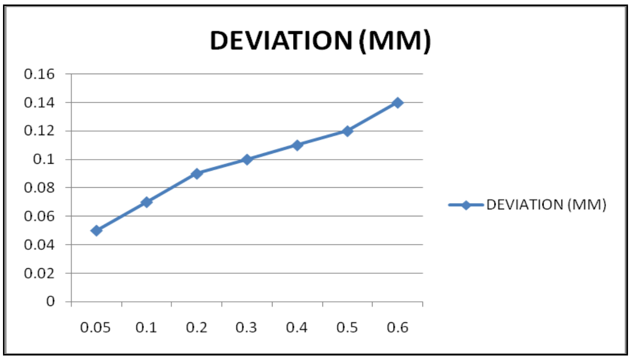
SPEED = 450 RPM FEED = 0.3

SR. NO	SPEED (RPM)	FEED (MM/REV)	DEPTH OF CUT (MM)	DIMENSION	DEVIATION	Surface Roughness µRa
1.	450	0.3	0.5	50.11	0.11	2.1
2.	450	0.3	0.7	50.15	0.15	2.5
3.	450	0.3	1.0	50.21	0.21	2.9
4.	450	0.3	1.2	50.26	0.26	3.2
5.	450	0.3	1.5	50.311	0.31	3.6
6.	450	0.3	1.8	50.34	0.34	4.0
7.	450	0.3	2.0	50.37	0.37	4.4

Graph of Deviation Vs Depth of cut at 450 rpm , 0.3 mm feed (mm/rev) , For machining EN9 using STD insert without use of MQL







SR. NO	SPEED (RPM)	FEED (MM/REV)	DEPTH OF CUT (MM)	DIMENSION	DEVIATION	Surface Roughness µRa
1.	750	0.05	0.05	50.05	0.05	1.0
2.	750	0.05	0.1	50.07	0.07	1.2
3.	750	0.05	0.2	50.09	0.09	1.4
4.	750	0.05	0.3	50.10	0.10	1.6
5.	750	0.05	0.4	50.11	0.11	1.8
6.	750	0.05	0.5	50.12	0.12	2.0
7.	750	0.05	0.6	50.14	0.14	2.1

OBSERVATIONS TABLE --b (Finishing)

SPEED = 1050 RPM

FEED = 0.05

3. CONCLUSIONS

As per the analysis & result, the conclusion of this paper is MQL technique offer better surface finish and dimensional accuracies than convectional lubrication in terms while machining of EN9 material. Also improve in tool life & reduction in tool wear & heat generation.

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I feel happiness in forwarding this paper as an image of sincere efforts. The successful paper publication reflects our work, efforts our guide in giving good information.

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